ACOUSTIC EMISSION MONITORING/ SEISMIC WAVE MONITORING

PROCEDURE ID: YMP-LBNL-TIP/TT 4.0 | REV. 1, MOD. 0 | EFFECTIVE: 09/08/00

1. PURPOSE

This Technical Implementing Procedure (TIP) describes the process developed to use seismic methods to monitor the change in acoustic emission activity and seismic energy propagation in thermally stressed rocks. Such an example is the effect of heating on the potential repository rock within the Exploratory Studies Facility (ESF) at the Yucca Mountain Site Characterization Project (YMP), and the monitoring of any cracking or jointing of the rock mass associated with heating.

2. SCOPE

This procedure applies to all LBNL personnel (or contractor personnel following LBNL procedures) involved in acquisition of acoustic emission data activities subject to Quality Assurance Requirements and Description (QARD), DOE/RW-0333P. Prior to conducting work described in Section 3.0 of this procedure, personnel acquiring acoustic emission data require training to this procedure.

For all technical activities, data collected using this procedure and any equipment checks that may be required shall be in accordance with this TIP and in full compliance with YMP Administrative Procedure (YAP)-12.3Q, *Control of Measuring and Testing Equipment and Calibration Standards.* Documentation resulting from actions taken under this TIP will be recorded in Scientific Notebooks as described in the Office of Civilian Radioactive Waste Management (OCRWM) Administrative Procedure (AP)-SIII.1Q, *Scientific Notebooks*. Measurements and calibrations of other equipment not specifically mentioned herein will be in full compliance with YAP-12.3Q. Electronic data maintenance, controls and transfers shall comply with YMP-LBNL-Quality Implementing Procedure (QIP)-SV.0, *Control of the Electronic Management of Data.*

If this procedure cannot be implemented as written, YMP-LBNL personnel shall notify the responsible Principal Investigator (PI) or designee. If it is determined that a portion of the work cannot be accomplished as described in this TIP, or would produce undesirable results, that portion of the work shall be stopped and not resumed until this procedure is revised per YMP-LBNL-

QIP-5.2, *Preparing Development Plans & Quality /Technical Implementing Procedures*.

If the responsible PI or designee determines that a modification or a revision to the TIP would cause an unreasonable delay in proceeding with the task, then an expedited change to the procedure, including documentation of deviation from the approved procedure, can be made according to YMP-LBNL-QIP-5.2. Such changes are subject to review, usually after the task has proceeded, and thus work performed under TIPs with expedited changes is done at risk of future invalidation.

Employees may use a controlled electronic or hard copy of this procedure; however, employees are responsible for assuring that the correct revision of this procedure is used. When this procedure becomes obsolete or superseded, it shall be destroyed or marked "superseded" to ensure that this document is not used to perform work.

3. PROCEDURE

3.1 Principle

As rock is heated in a confined underground environment, thermal expansion can cause cracking of the rock mass or movement along pre-existing fractures or joints. Seismic methods have been shown to assist in resolving such changes. Acoustic emissions resulting from any cracking or movement can be registered by accelerometers emplaced in the rock mass designed to detect extremely small displacements in the host material. Any change in the rate of this activity can be recorded and integrated over time and analyzed both spatially and temporally. The location and timing of such changes in activity are expected to correspond to those areas where physical change or disturbance in the rock mass is occurring.

3.2 Equipment Description:

The configuration of the acoustic emission/seismic monitoring experiment consists of accelerometers (Wilcoxin Research or similarly specified; 100 Hz to 10,000 Hz at 3db points, 100mv/g sensitivity or greater) emplaced in locations throughout the rock mass under investigated. Depending on the experimental environment the accelerometers may or may not be replaced or repaired during the duration of the experiment. This may be due to backfilling of boreholes, locking off the boreholes or otherwise restricted access to the boreholes

where the accelerometers reside. During the Drift Scale Test, for instance, the location of the accelerometers is such that the heaters and high temperatures prevent any access to the accelerometers once the test has begun. A sufficient number of accelerometers are emplaced such that a redundancy exists in the data collection and failure of one or more accelerometers will not jeopardize the experiment. At least 5 sensors per experiment need to be operating for location of a micro seismic event. The data (seismic wave arrival times) collected from the functioning accelerometers will be sufficient to locate those areas of acoustic emission activity based on standard principles of triangulated seismic detection. The signals from the accelerometers are then transmitted to a central location over coaxial cables to be detected and recorded on the acquisition computer.

Signal filtering controls are installed based on evaluation of baseline data recorded just prior to the start of the experiment. The filtering of all incoming accelerometer signals is accomplished by way of a four pole high pass filter with a corner frequency of 1000 Hz. The filter roll off is approximately 2 dB down at 1000 Hz, 4 dB down at 750 Hz, and 12 dB down at 500 Hz. This is done in an attempt to isolate the number of events being recorded that are outside of the frequency bandwidth of the acoustic emissions (1000-10000 Hz). Such low frequency activity is likely the result of activity not directly related to the experiment (forklifts, man trains, tunneling, etc.) and as such is not desirable for recording in this test. The triggering mechanism for the recording system is incorporated into the filtering system. Incoming signals from the accelerometers are filtered before they enter the trigger control box. The control box must register signals of sufficient strength (50 mV) on a predetermined number of the accelerometer data channels before the recording system is triggered and data are recorded on all data channels.

3.3 Data Acquisition

The following step shall be taken by the staff members when acquiring acoustic emission data:

3.3.1 Record data continuously with data transfer being performed by way of a removable hard disk drive. Each visit to the recording system results in the downloading of any acquired data files and the subsequent restarting of the recording system. The data are acquired by RC Electronics, ISC-67.

3.3.2 Perform a preliminary analysis of the acquired data using the

recording system as a digital oscilloscope. This is done to determine if a data file is comprised of primarily noise or whether any seismic activity has been recorded. Visual inspection of the recorded data shall be done only by a competent individual who has at least some familiarity with seismic waveforms. Noise records will not be comprised of a coherent waveform and typically consist of randomly occurring "spikes" of medium to high amplitude. Seismic activity is distinguished by coherent waveforms on multiple channels exhibiting moveout and variable amplitudes.

3.4 Accelerometer and Recording System Check

3.4.1 Accelerometer Check

The accelerometers shall be checked both before the start of the test and periodically throughout the experiment during periods of data downloading. The check shall consist of a "tap test" or "hammer blow test" which is a commonly applied procedure in the seismic or acoustic data acquisition industry. The "tap" or "hammer blow" test consists of one of the following depending upon the equipment accessibility: 1) the accelerometer itself is gently tapped and its output is monitored on an appropriate device (e.g. an oscilloscope); or 2) the rock mass encompassing the embedded accelerometer is hammered and the accelerometer output is monitored on an appropriate device (e.g. an oscilloscope). The above steps and results shall be recorded in the Scientific Notebook upon completion of each "check."

3.4.2 Recording System Check

Checking of the Recording System shall be performed periodically by making use of a standard waveform generator and a calibrated oscilloscope operating under the guidelines specified in YAP12.3Q (note: only the oscilloscope need be calibrated as the waveform / signal generator is calibrated relative to the oscilloscope). The function generator is used to input a signal of known frequency and amplitude into a single data channel while the waveform received by the recording system is monitored on the external oscilloscope. If operating properly, the channel will register / record the generated signal within an acceptable range for a given input voltage, frequency and amplitude (i.e. the input signal and the recorded signal should closely resemble one another). This "check" procedure is described in detail in 3.4.3 below. Only those channels checked and operating correctly will be used. All of the above processes and calibration data shall be recorded in the Scientific Notebook as per

AP-SIII.1Q.

3.4.3 Check Procedure for Recording System

The "check" procedure will consist of the following:

1. A function generator is used to generate a signal of known frequency (100, 500, 1000, 2000, 4000, 6000, 8000, and 10000Hz) and fixed voltage (1.0 Volt peak to peak amplitude).

2. This signal is input into each of the recording system data channels over connecting coaxial cables.

3. The frequency and amplitude of the waveform received by the data channel is monitored on a calibrated oscilloscope and recorded in the scientific notebook.

4. The output frequency and amplitude values are compared to the known input waveform and judged to be in compliance or out of compliance depending upon their agreement.

If a data channel's frequency and amplitude response does not closely match the input waveform, that particular data channel will no longer be considered as functioning properly. All data acquired by this data channel during the period of time between "checks" shall be flagged or marked appropriately as "suspect." Subsequent data processing shall be used to determine whether any data acquired by this channel is usable. Furthermore, all data acquired subsequently by this channel will be judged to be out of compliance and will not be considered in the analysis of the microseismic data until replaced or repaired by the manufacturer.

3.5 Control and Reduction of Electronic Data:

The following steps shall be taken to ensure completeness and accuracy of the data and the security of the data including integrity of the data.

3.5.1 The acoustic emission data are received directly from the accelerometers into the computer and stored on the computer's hard disk. Download a copy from the computer's internal hard disk to a removable disk drive to be transported to LBNL for further processing.

3.5.2 Make a comparison between the internal hard disk version and the removable disk version to ensure that the file sizes are identical, and perform a brief spot check of some of the data to confirm

successful transfer. This ensures that in the event of data loss or file corruption, the problematic file or data error can be resolved before leaving the experimental location. This check shall be documented in the scientific notebook and shall include the dates of data checked and transferred to removable disk.

3.5.3 At LBNL, transfer the data from the removable disk onto a local computer hard disk drive and store the removable disk separately for safekeeping. Access to the computer is limited by lock and key. Perform a comparison between the hard disk version and the removable disk version to ensure that the file sizes are identical, and perform a brief spot check of some of the data to confirm successful transfer. All output files generated during data acquisition are stored on a networked mainframe computer located at LBNL. The data are then processed for location, rate of activity, and amount of activity over periodic time frames. Standard location analysis using first arrival time can be used as Geiger's or Inglade's method (T.V. McEvilly and E.L. Majer, 1982).

4. RECORDS

4.1 QA records

Records generated as a result of this TIP are entries in scientific notebooks or attachments to such notebooks and the electronic data files associated with these entries.

4.2 Non-QA Records

None

4.3 Controlled Documents

Technical Implementing Procedure

4.4 Records Center Documents

Records associated with this procedure shall be submitted to the Records Coordinator for transmittal to the Records Processing Center (RPC) in accordance with AP-17.1Q, *Record Source Responsibility for Inclusionary Records*.

5. RESPONSIBILITIES

5.1 The Principal Investigator (PI) is responsible for assuring full compliance with this procedure and providing training thereof. The PI is responsible for overseeing and coordinating TIP preparation, review, distribution, revision, and recommendation of rescission.

5.2 Staff Members involved in the preparation or review of procedures are responsible for following this procedure and turning over related documentation to the Records Coordinator for submittal to the RPC in accordance with AP-17.1Q. Related data shall be turned over to Technical Data Coordinator for submittal to YMP Technical Data Management System (TDMS) in accordance with and AP-SIII.3Q, *Submittal and Incorporation of Data to the Technical Data Management System*.

6. ACRONYMS AND DEFINITIONS

6.1 Acronyms

AP	OCRWM Administrative Procedure
ESF	Exploratory Studies Facility
LBNL	Lawrence Berkeley National Laboratory
M&TE	Measuring and Testing Equipment
NIST	National Institute of Standards and Technology
OCRWM	Office of Civilian Radioactive Waste Management
PI	Principal Investigator
QIP	Quality Implementing Procedure
RPC	Records Processing Center
TIP	Technical Implementing Procedure
TDMS	Technical Data Management System
YAP	YMP Administrative Procedure
YMP	Yucca Mountain Site Characterization Project

6.2 Definitions

Check: The process of establishing the accuracy of a standard or measuring device, which may require resetting parameters on the device to improve its accuracy.

Staff Member: Any scientist, engineer, research or technical associate, technician, or student research assistant performing quality-affecting work for YMP-LBNL.

Technical Implementing Procedure: Each TIP describes YMP-LBNL technical tasks that are repetitive and standardized.

7. REFERENCES

McEvilly, T.V., and Majer, E.L., 1982, ASP: An automated seismic processor for microearthquake networks: *Seismological Society of America. Vol.72, No.1, pp.303-325.*

AP-17.1Q, *Record Source Responsibility for Inclusionary Records*

AP-SI.1, *Software Management*

AP-SIII.1Q, *Scientific Notebooks*

AP-SIII.3Q, *Submittal and Incorporation of Data to the Technical Data Management System*

DOE/RW-0333P, *Quality Assurance Requirements and Description (QARD)*

YAP-12.3Q, *Control of Measuring and Test Equipment and Calibration Standards*

YMP-LBNL-QIP-5.2, *Preparing Development Plans & Quality/Technical Implementing Procedures*

YMP-LBNL-QIP-SV.0, *Control of the Electronic Management of Data*

8. ATTACHMENTS

None

9. REVISION HISTORY

9/30/98 Revision 0, Modification 0

This is the initial issue of this procedure. Derivative of a scientific

notebook procedure/methodology prepared by K. Williams and reviewed by Y.Tsang. It was part of the scientific investigation in the Scientific Notebook YMP-LBNL-YWT-ELM-1.1.2.

09/08/00 – Revision 1, Modification 0:

Incorporated references to current APs, YAPs, and QIPs. Deleted Section 3.3.3. Deleted responsibilities for staff members not directly responsible for implementing this procedure. Revised and corrected procedures concerning calibration of M&TE. Calibration procedure was revised to reflect that previous methodology was, in fact, a "check" rather than a measure of calibration compliance to NIST or Rev. 1, Mod. 0 incorporates this use of a check to ensure proper functioning of the acoustic emission monitoring system and removes the explicit calibration of the M&TE from the requirements of this TIP. M&TE calibration standards and procedure are explicitly dealt with through an M&TE Justification form as per YAP-12.3Q.

10. APPROVAL

Signature on file Preparer: Ken Williams	Date
Signature on file Technical Reviewer / PI: Ernest Majer	Date
Signature on file Technical Reviewer: John Peterson	Date
Signature on file EA Reviewer: Vivi Fissekidou	Date
Signature on file OQA Concurrence: Stephen Harris	Date
Signature on file Project Manager: Gudmundur Bodvarsson	Date